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ROLE OF CHLOROPHYLL-A AND SEA SURFACE TEMPERATURE ON FISH PRODUCTION: A STUDY FROM EXCLUSIVE ECONOMIC ZONE OF SOUTHEAST COAST OF INDIA

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Abstract:

This study examines how SST and chlorophyll-a influence fish production along the Tamil Nadu Coast from 2017 to 2021. The results show annual SST ranges between 27.08°C and 30.75°C (highest April-June, lowest December-February) and chlorophyll-a concentration varies between 0.16 and 0.8mg/m³ (maximum July-September, minimum March-May). A significant positive correlation is identified between chlorophyll-a and fish catch, while SST shows a significant negative correlation with fish catch. The study concludes that SST and chlorophyll-a, play a crucial role in regulating fish production. Continuing increases in SST driven by global warming may reduce primary productivity and threaten India's blue economy by limiting food availability for fish populations.

Keywords: Sea Surface Temperature, Chlorophyll-a, Exclusive Economic Zone, Fish catch, Giovanni.

1. INTRODUCTION

Our environmental conditions play a major role in the existence of life on Earth. Similarly, in a marine environment, the growth and development of the fish populations depend on nutrient availability and favourable physicochemical conditions. Changes in environmental condition scan influence fish production, which is reflected in India's blue economy. However, fishing in India is a major sector within the economy, and it contributes 1% of its total GDP, and Tamil Nadu ranks 4th place in total fish production of the nation(Ngasotter et al., 2020). Tamil Nadu is a leading exporter of marine products in India. The fishing activity in the exclusive economic zone is referred to as coastal fisheries (Juda, 1991). Currently, approximately 40% of the world's population lives within 100 kilometres of the coast. Coastal fisheries are very important and provide food, nutrients, and livelihood to the coastal population.Fish production in India increased from **16.24 million metric tonnes in 2021–2022** to **17.35 million metric tonnes in 2022–2023**, reflecting a **growth rate of 6.8%**. Marine exports from India are projected to rise from **1,149,341 metric tonnes**,

valued at **₹43,717.26 crore** in **2020–2021**, to **1,735,286 metric tonnes**, valued at **₹63,969.14 crore** in **2022–2023**, representing a **51% increase in quantity** and a **36% increase in value** (Najmudeen, 2023). According to MPEDA, during the **financial year 2023–24**, India exported an **all-time high of 1,781,602 metric tonnes of seafood**, worth **US $7.38 billion** (₹60,523.89 crore). According to Anagha (2022), shifts in fish catch rates pose significant challenges to both the coastal population and the Indian economy.Therefore, monitoring the coastal environmental status is essential for sustainable development. The coastal fishery sector in India faces several challenges, including overfishing, habitat destruction, and the impact of climate change(Anagha, 2022). To understand coastal fisheries, we need environmental data about coastal waters. In the marine environment, the growth and development of fish populationsmainly dependon nutrient availability and favourable physicochemical conditions(Vivekanandan, 2011). Oceans continuously interact with the atmosphere, and sea surface temperature (SST) can also have profound effects on the global climate. Increases in SST have led to an increase in the amount of atmospheric water vapour over the oceans(Nemani et al., 2001). This water vapour feeds weather systems that produce precipitation, increasing the risk of heavy rain and snow. Although many major river systems bring in large quantities of nutrients, narrow shelves, persistent cloud cover, and low light penetration are responsible for low productivity (Prasanna Kumar et al., 2002;Vinayachandran, 2009).

The information about spatial and temporal variation in biological and physical properties of coastal water provides a more comprehensive understanding of the productivity status of coastal waters. The primary production of the marine environment mainly depends on SST and physicochemical parameters(Satpathy et al., 2011). By monitoring the above-mentionedparameters, we can gain insights into fish production ina particular region.Specifically, SST and chlorophyll-a (Picado et al., 2014;Ningsih et al., 2021; Rahman et al., 2019;Sarangi, 2019) significantly influence fish production. Remote sensing serves as a reliable tool to obtain information about these parameters (Prados et al., 2010), enabling more effective analysis of spatial and temporal distribution that can be measured from space (Das et al., 2012). It is the only way to monitor changesin marine ecosystems, which exhibit high-resolution physical and biological variability on a daily, weekly, monthly, and seasonal basis.SST and chlorophyll-a indicate close coupling(Nurdin et al., 2013). The variability of chlorophyll-a is related to the seasonal monsoon due to changes in water conditions, such as SST. Chlorophyll-a pigment concentration serves as a convenient index of phytoplankton biomass, and SST is a crucial factor influencing phytoplankton growth.In the Bay of Bengal, Chlorophyll concentration was low(8 mg/m^3) during April, May, and June, whereas July, August, September, and October report higher concentrations (12 mg/m^3) (Sarangi, 2019). During winter months, chlorophyll concentration increases with a decrease in SST, whereas in summer months, it decreases with an increase in SST. Consequently, the declining trend in chlorophyll-a concentration due to warmer SST and high Sea Surface Humidity(SSH) significantly impacts the ocean's primary productivity and may lead to diminishing the marine resources(Annapurna & Krishna, 2021).

In the Bay of Bengal(BoB), winter SST varies from 25.7℃in the north to 28.7℃ in thesouth, while summer SST ranges from 28℃in the east to 28.6℃ in the west. The objectives of this study are to investigate the relationship between SST and chlorophyll-a concentration from 2017 to 2021, determine the preferred range of SST and chlorophyll-a for-fish production, and map the potential fishing grounds in the Exclusive Economic Zone (EEZ) of Tamil Nadu.

2. STUDY AREA:

The exclusive economic zone (EEZ) of Tamil Nadu is located between Chennai (13°04’57"N, 80°16’15"E) and Kanyakumari (8°04’40"N, 77°32’28"E). It encompasses a 1,076 km long coastline with an EEZ of 1.9 lakh sq. km in the Bay of Bengal.Figure 1 represents a potential fishing zone and Exclusive Economic Zone (EEZ) zone identified by Nammalwar et al. (2013).Coastal **Tamil Nadu**is influenced by key ecological zones such as the **Bay of Bengal upwelling zones, the Gulf of Mannar Biosphere Reserve, and the Palk Bay ecosystem**. The coastal region of Tamil Nadu is unique, and it has several estuaries, biosphere reserves, mangrove forests, and small islands, which act as spawning and nestling grounds for a variety of fish species. It is equipped with 6 major and 3 medium fishing harbours, alongside 36 fish landing centres and 254 fish landing points. This extensive infrastructure collectively harvests over 85 metric tons of fish annually (Berrick et al., 2008).Fish catches were significantly higher in Kancheepuram, Tiruvallur, and Chennai compared to the southern part. Regarding the climate, the study area differs from other parts of India due to the southeast coast receiving 70% of its rainfall during the northeast monsoon. Both the southwest and northwest monsoons influence the southern part of the study area. Reasonable freshwater discharge with nutrients, which enhances the productivity of the study area. Surface water temperatures ranged from a maximum of 32.0°C in summer to a minimum of 27.5°C during the monsoon season. Monsoon dominates the regional climate, resulting in an average annual precipitation of 96 cm.The seasonal variation in chlorophyll distribution in the surface water of the study area showed a maximum during the summer and pre-monsoon seasons, while it was minimum during the monsoon season. Chlorophyll concentration and primary productivity remained high during the summer months.

3. METHODS

In this study, satellite-derived SST and chlorophyll-a data was collected by using Giovanni portal from 2017 to 2021. Monthly average SST data were obtained from the MODIS-Aqua Level 3 product (11 μm daytime band) at a 4 km spatial resolution. Additionally, the area-averaged chlorophyll-a data was collected from a time series of monthly 4km (MODIS-Aqua MODIS-L3m-CHL) in milligrams per cubic meter($mg/m^{3)}$from2017 to 2021(Prados et al., 2010). Available fish catch data from the Fisheries Resources Assessment Division of the Central Marine Fisheries Research Institute (CMFRI), Kochi, were tabulated along with SST, chlorophyll-a, and correlations

were established.To assess the linear association of SST, chlorophyll-a, and fish catch, we have performed the Spearman rank correlation test, which estimates the strength and direction of the correlation. For statistical analyses, we used SigmaPlot version 14.0 to plot the pairwise correlation between the variables.

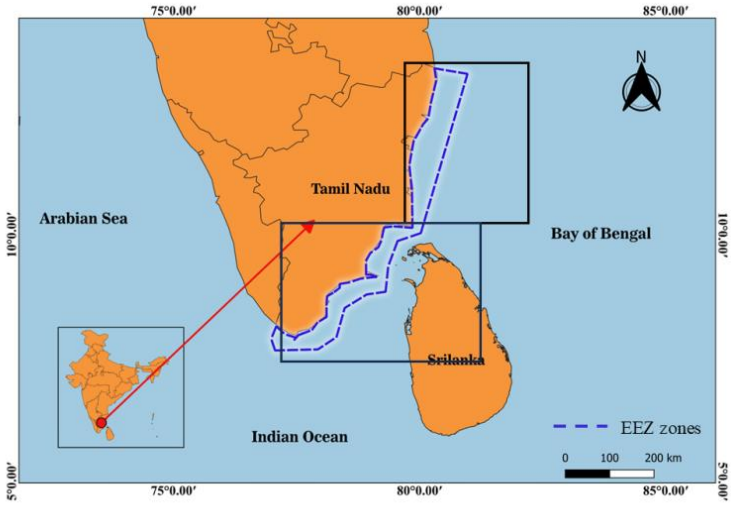


Fig 1: Study area map showing the Exclusive Economic Zone (EEZ) and a black colour rectangle box denoting a potential fishing zone of southeast India.

4. RESULTS AND DISCUSSION

4.1 SST, Chlorophyll-a and Fish Production

The results show that annual SST ranges between 27.08°C and 30.75°C, with relatively higher temperatures (29.3°C–31.08°C) recorded during April, May, and June of each yearand lower temperatures (26°C–27.56°C) recorded during December, January, and February (Fig.2). Moderate SST was recorded between June, July, and August.In contrast, chlorophyll-a concentration varied between 0.16 and 0.8 mg/m^3. The annual maximum chlorophyll-a concentration occurred during July, August, and September (0.4–0.8 mg/ m^3), and minimum values were observed in March, April, and May (Fig.2).

This analysis reveals an annual relationship between fish catche sand chlorophyll-a. Figure3 indicates that 2019 had the highest fish production in the last five years. The main varieties of fish catches in this study include Lesser sardines, Oil sardines, Silverbellies, Cephalopods, Tunnies, Scads, Indian mackerel, Penaeid prawns, and *Odonus niger*. Figure 4 highlights the dominant fish production over the last five years,with Lesser sardine being highly abundant from 2017–2022, followed by Silverbellies. In 2019, *Odonus niger* was prevalent and found only during that year.*Odonus niger*likely inhabits reef channels or long slopes that have strong water currents,which prevent them from being swept away by rocks and crevices.In 2017, Tamil Nadu's land yielded 6,55,000 metrictons,

representing a 7% decline. Despite a 36% drop in oil sardine landings, Lesser sardines regained their previous prominence, accountingfor more than 100,000 metric tons (Fig.3). The peak fishing season faced disruptions from three cyclones and heavy rains that struck the region in 2021. During July to September, there was a higher landing percentage due to less moisture advection and reduced convective activity in the southwest Bay of Bengal region during the pre-monsoon season, which may have contributed to below-normal rainfall over Tamil Nadu.The weather remains consistently pleasant during this time, with minimum rainfall.

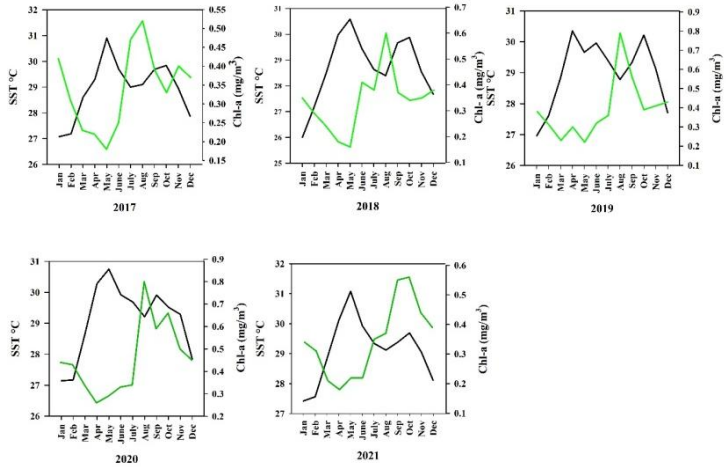


Fig 2: Variation between the monthly mean Chlorophyll-a and SST during 2017 -2021. The black line demonstrates the SST, and the green line demonstrates the Chlorophyll-a.

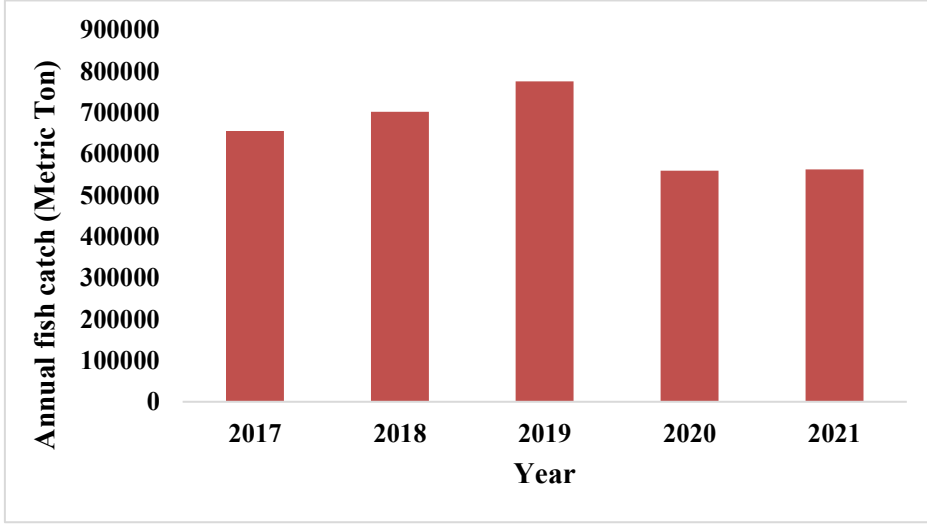


Fig 3: Shows the annual fish catch data for southeast India during 2017-2021.

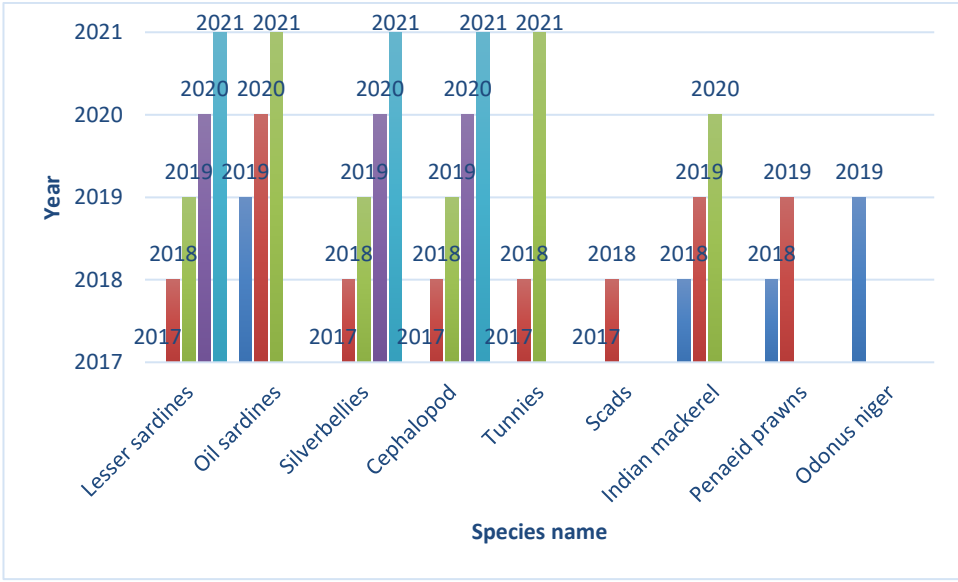


Fig 4: Shows the top five dominant varieties of fish caught in southeast India for the past five years (2017-2021).

The variation of SST and chlorophyll-a in the study area has significant implications for fishery management and conservation. Seasonal changes in these parameters can help identify potential fishing zones and monitor the health of the marine ecosystem. The monthly distribution of SST and chlorophyll-a produced for the study area reveals clear spatial patterns. The results show that SST increased from March to May, influencing both fish catch and chlorophyll-a concentration. The rise in mean SST is a key indicator of ocean warming, affecting fish reproduction, growth, and migration (Shoba et al., 2014). During 2017–2021, chlorophyll-a increased during July–September (Fig. 2). Tomczak and Godfrey (1994) reported that upwelling occurs in this region from January to July and downwelling from August to December. Low SST and high chlorophyll-a levels could be associated with southwest Bay of Bengal upwelling (Mishra et al., 2006; Sahu et al., 2016). Maximum chlorophyll-a concentrations occur at the onset of the Northeastern Monsoon (NEM). Sarangi (2019) also noted high chlorophyll biomass in the Gulf of Mannar and Palk Bay, and predicted consistently high fish catch in the southern Bay of Bengal. Changes in wind direction, speed, and ocean circulation further influence surface water temperature by mixing deeper, nutrient-rich waters (Vivekanandan, 2011).

4.2 Correlation between Chlorophyll-a and SST

The relationship between SSTand chlorophyll-a was attempted in this study.Figure 2 illustrates the variation between the monthly mean chlorophyll-a and SST during 2017–2021. The correlation of SST and chlorophyll-a reveals the coefficient of determination (R^2) and correlation coefficient from 2017 to 2021 (Fig.5). The negative correlation coefficient for all years indicates a negative linear trend between SST and chlorophyll-a. This negative

relationship occurs because higher SST generally enhances water column stratification, which reduces vertical mixing and limits the upward transport of nutrients from deeper layers into the euphotic zone. However, none of these correlations are statistically significant at the 0.05 level, as the p-values are all greater than 0.05 (Table 1). Consequently, we cannot reject the null hypothesis that there is no significant correlation between SST and chlorophyll-a in the study area.

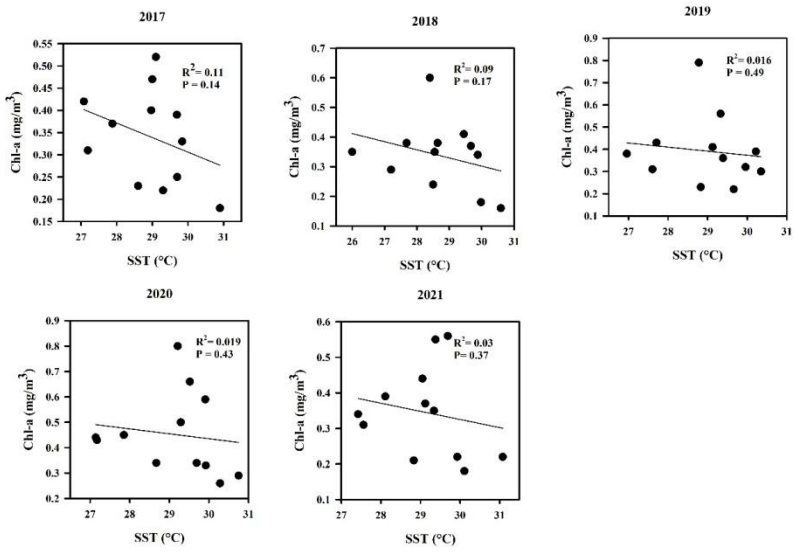


Fig 5: Relationship between SST and Chlorophyll-a during 2017 -2021.

Table 1: R-square, correlation coefficient and p-value for the linear regression model between SST and Chlorophyll-a for each year.

Year	R-Square (R^2)	Correlation Coefficient	P-Value
2017	0.11	-0.33	0.14
2018	0.09	-0.30	0.17
2019	0.01	-0.10	0.49
2020	0.01	-0.12	0.43
2021	0.03	-0.17	0.37

Our results indicate that SST and chlorophyll-a concentrations were negatively correlated (Fig. 5), consistent with previous regional studies (Rahman et al., 2019; Hidayat et al., 2023). Various researchers have examined the inter-annual and seasonal relationship between chlorophyll-a and SST (Ningsih et al., 2021; Rahman et al., 2019; Castillo et al., 1996). This inverse relationship is likely driven by the upwelling in the Southwest Bay of Bengal and the intrusion of nutrient-rich water (Mishra et al., 2006; Sahu et al., 2016). Seasonal monsoon currents (SMA and NMC) and nitrate availability also influence chlorophyll-a distribution (Sarangi, 2019). During the summer monsoon (June–September), the West India Coastal Current (WICC) flows southwesterly along the west

coast and eastward along the east coast, further affecting SST and nutrient dynamics (Shenoi et al., 1999).

4.2 Correlation betweenChlorophyll-a, SST, and Fish catch:

The variations of SST, chlorophyll-a, and fish catch in the study area are presented in Figure 6. The result showed a significant negative correlation between SST and fish catch (R^2 = 0.37; p<0.0501) as well as a significant positive correlation between chlorophyll-a and fish catch (R^2 = 0.97; p<0.05). The preferred range of SST for fish production was found to be 30.01± 0.21℃, while the preferred range of chlorophyll-a was found to be 0.31 ± 0.10 mg/m^3(Fig. 6).Fish catch data shows that annual fish production was higher during July, August, and September, suggesting that an increase in chlorophyll-a concentration leads to an increase in the fish catch. The annual fish production and chlorophyll-a were positively correlated; whenever chlorophyll-a increased, fish production also increased. This finding supports the hypothesis that a higher chlorophyll-a concentration indicates higher primary productivity and food availability for fish in the study area.

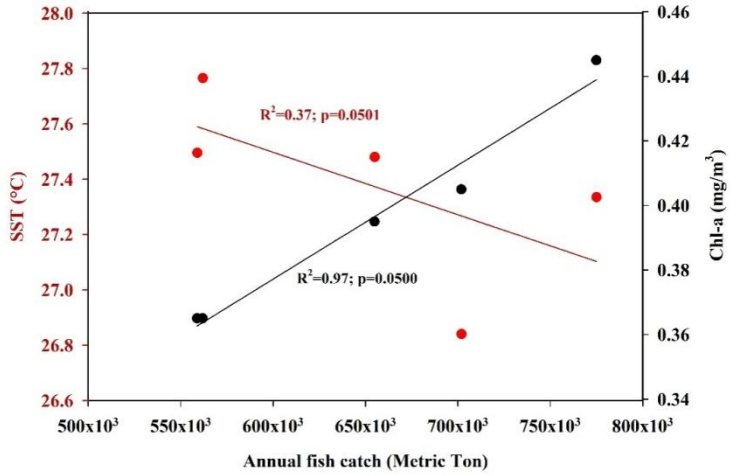


Fig. 6: Red colour shows the variation between the annual SST and fish catch. And black colour shows Chlorophyll-a and fish catch during 2017 -2021. The X-axis shows the annual fish catch, the Y-axis on the right side shows the chlorophyll-a, and the left side shows the SST.

Several studies recommend analysing the relationship between SST, chlorophyll-a, and fish catch, and demonstrates that chlorophyll-a significantly influences marine capture fisheries production, with fish populations thriving within optimal monsoon-driven temperature and productivity ranges(Ningsih et al., 2021; Nurdin et al., 2013; Sachoemar et al., 2012; Suwannathatsa & Wongwises, 2013; Kämpf & Chapman, 2016).We observed a significant positive correlation between chlorophyll-a and fish catch (R^2 = 0.97; p < 0.05) (Fig. 6), consistent with previous findings on optimal environmental conditions for Indian

waters. Sachoemar et al. (2012) noted that fish productivity is strongly influenced by seasonal changes in chlorophyll-a, with higher productivity corresponding to higher chlorophyll values. Ningsih et al. (2021) similarly reported higher fish production in areas with elevated chlorophyll-a concentrations. However, fish production was consistently low during April–June throughout the study period. This aligns with the observation that chlorophyll-a peaks from July–September, coinciding with increased fish landings (Fig. 6). Other studies have highlighted seasonal variability in species distribution driven by temperature and salinity (Castillo et al., 1996). The reduction in fish catch in 2020 compared to 2019 is likely due to COVID-19 restrictions rather than environmental limitations.

5. CONCLUSION:

This study highlights the seasonal variability of SST, chlorophyll-a, and fish catch along the Tamil Nadu EEZ from 2017 to 2021. SST peaked during April–June, while chlorophyll-a reached its maximum during July–September. Fish landings, dominated by Lesser sardines, Silverbellies, and other pelagic species, were highest in 2019.A consistently negative but non-significant relationship was found between SST and chlorophyll-a. However, fish catch showed a significant negative correlation with SST and a strong positive correlation with chlorophyll-a, indicating that primary productivity strongly influences fish abundance. The preferred environmental ranges for optimal fish production were ~30°C SST and ~0.31 mg/m³ chlorophyll-a. Overall, the results demonstrate that monsoon-driven changes in temperature and chlorophyll-a productivity play a central role in determining fish availability in the region. Continued monitoring of these oceanographic variables is essential for improving fisheries management under changing climatic conditions.

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Conflict of interest:

The authors declare no competing interests.

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